than myself, by whose verdict the question will ultimately be decided, and regretting that my own opportunities of collecting evidence have been so few and far between.

Loughlingstown, Co. Dublin.

Letter from an Officer in the Merchant Navy on the Application of Corrections for Change of Temperature to the Rates of two Chronometers during a voyage from Liverpool to Calcutta.

(*Communicated by Mr. Hartnup.*)

During my last voyage from Liverpool to Calcutta, on board the ship "Tenasserim," I had an opportunity, through the kindness of the Commander, Captain T. C. Potts, of testing the practical value of your method of finding the rate of a chronometer at sea by the application of corrections due to change of temperature.

In 1873 I obtained a copy of your Report to the Marine Committee of the Mersey Docks and Harbour Board for the preceding year, in which you have given examples of the method of making the necessary calculations, and I have followed the instructions there given. The two chronometers used on the voyage were named "J. Basnett & Son, No. 713," and "Thomas Blundel, No. 209." The data from which I made my calculations I obtained from two certificates given by you at the Bidston Observatory in September 1871, from which I obtained the following results:—

No. 209.

Rate in 55° = $-5^{\circ}\cdot58\ r$
" 70° = $-4^{\circ}\cdot00\ r'$
" 85° = $-2^{\circ}\cdot70\ r''$

$r - r' = -1^{s}\cdot58 = d$
$r' - r'' = -1^{s}\cdot30 = d'$
$d - d' = -0^{s}\cdot28$
$d + d' = -2^{s}\cdot88;$

$$C = \frac{2(d-d')}{30^2} = \frac{-0\cdot56}{900} = -\cdot00062;$$

$$T - 70 = \frac{d+d'}{C \times 60} = \frac{-2\cdot88}{-0\cdot0372} = +77\cdot4;$$

$$T = 70 + 77\cdot4 = 147\cdot4;$$

$$R = r' - (T-70)\frac{d+d'}{60} = -4\cdot00 + 77\cdot4 \times \cdot048 = -0\cdot28.$$

No. 713.

Rate in 55° = $-0^s.72\ r$
„ 70° = $-0^s.27\ r'$
„ 85° = $-1^s.35\ r''$

$r - r' = -0^s.45 = d$
$r' - r'' = +1^s.08 = d'$
$d - d' = -1^s.53$
$d + d' = +0^s.63;$

$$C = \frac{2(d-d')}{30^2} = \frac{-3.06}{900} = -.0034;$$

$$T - 70 = \frac{d+d'}{C \times 60} = \frac{+0.63}{-0.204} = -3.1;$$

$$T = 70 - 3.1 = 66.9;$$

$$R = r' - (T-70)\frac{d+d'}{60} = -0.27 + 3.1 \times 0.0105 = -0.24.$$

From the above calculations we have the following results :—

	Mean Daily Rate. In 55°	In 70°	In 85°	C	T	R
	s	s	s		°	s
No. 209	−5.58	−4.00	−2.70	−0.00062	147.4	−0.28
No. 713	−0.72	−0.27	−1.35	−0.0034	66.9	−0.24

Let N = any number of degrees from T; then the rate at $T \pm N = R + C \times N^2$.

On the arrival of the "Tenasserim" at this port (Liverpool) in December 1873, the errors of both the chronometers were found by the time gun; and on her sailing on January 21, 1874, the errors were again obtained by the same means. The rates were found by dividing the difference of these errors by the number of days which elapsed between these two determinations. The following were the errors and rates as found, on January 21, 1874, by means of the time gun :—

No. 209.	No. 713.
Slow on G.M.T., $0^h\ 1^m\ 11^s.0$.	Slow on G.M.T., $0^h\ 31^m\ 2^s.0$.
Mean daily rate while in port losing, $1^s.2$.	Losing $0^s.8$.

The temperature to which the chronometers were exposed while in port was as nearly as I could ascertain 55° Fahrenheit; therefore in 55° the rate of No. 209 had between September 1871 and January 1874 altered from losing $5^s.6$ to losing $1^s.2$, and the rate of No. 713 had altered from losing $0^s.7$ to losing $0^s.8$. I find from your Report that the two factors C and T do not often alter, unless the chronometer is cleaned or repaired (which neither of them have been since September 1871). I have therefore assumed C and T to have remained constant, and I

have altered R in both chronometers agreeably to the above determinations of the ratio while in port. With these data, and following the rules laid down in your Report, I have calculated the following table of rates for every 5° of temperature (from 50°—90°), and using it, I have found the error in G.M.T. of each chronometer for every fifth day from January 21 to May 31, 1874:—

Table of Rates for every 5° of Temperature.

	50°	55°	60°	65°	70°	75°	80°	85°	90°	95°
	s	s	s	s	s	s	s	s	s	s
No. 209	−1·8	−1·2	−0·6	−0·1	+0·4	+0·9	+1·3	+1·7	+2·1	+2·2
No. 713	−1·3	−0·8	−0·5	−0·4	−0·4	−0·6	−0·9	−1·4	−2·1	−2·4

Captain Potts has been good enough to supply me with simultaneous readings of the faces of the two chronometers for every day of the voyage. The temperatures given are the means for each preceding five days obtained from the readings of a Board of Trade thermometer (which was kept in the chronometer-room) at 9 A.M. daily.

The results of my calculations, and the Observations of Captain Potts, are given in the Table on the following page.

On May 26, 1874, the errors of the two chronometers on G.M.T. were found to be:

	No. 209.	No. 713.
	h m s	h m s
By the Calcutta time gun	Fast 0 0 15·5	Slow 0 33 3·5
By calculation from rates corrected for change of temperature	Fast 0 0 19·0	Slow 0 33 12·0
Differences, or errors of longitude, by chronometer	0 0 3·5	0 0 8·5

You will see by the Table from the calculations for May 31, 1874, that, by correcting the rates for change of temperature, the two chronometers differed from each other in the G.M.T. shown by them by only *two seconds*; but by using the rates found in Liverpool in 55° temperature, they differed from each other to the large amount of *four minutes and fifty-two seconds* of time, or one degree and thirteen minutes of longitude.

Date. 1871.	Errors on Green. M.T. from calculations with Rates corrected for Change of Temperature. No. 209.	Errors on Green. M.T. from calculations with Rates corrected for Change of Temperature. No. 713.	Difference between the two Chronometers from Calculation.	Difference between the two Chronometers from Comparison with each other.	Differences of Green. M.T. between the two Chronometers from Rates Corrected for Change of Temp.	Differences of Green. M.T. between the two Chronometers from Rates Uncorrected for Change of Temp.	Mean Temp. Fahr.
	m s	m s	m s	m s	m s	m s	s
Jan. 21	−1 11·0	−31 2·0	29 51·0	29 51·0	0 0·0	0 0·0	00
26	−1 18·0	−31 7·0	29 49·0	29 44·5	0 4·5	0 4·5	53
31	−1 23·5	−31 10·5	29 47·0	29 44·0	0 3·0	0 3·0	56
					. . . .	. . . .	
Feb. 5	−1 26·0	−31 13·0	29 47·0	29 47·0	0 0·0	0 2·0	61
10	−1 26·0	−31 15·0	29 49·0	29 53·0	0 4·0	0 10·0	66
15	−1 21·5	−31 18·0	29 56·5	33 3·0	0 6·5	0 22 0	75
20	−1 15·0	−31 22·5	30 7·5	30 18·0	0 10·5	0 39·0	80
25	−1 9·0	−31 26·5	30 17·5	30 33·0	0 15·5	0 56·0	79
Mar. 2	−1 3·5	−31 30·0	30 26·5	30 44·0	0 17·5	1 9·0	77
7	−1 5·5	−31 32·5	30 27·0	30 45·0	0 18·0	1 12·0	62
12	−1 9·0	−31 35·0	30 26·0	30 46·5	0 20·5	1 15·5	59
17	−1 11·5	−31 37·5	30 26·0	30 47·5	0 21·5	1 18·5	61
22	−1 17·5	−31 41·5	30 24·0	30 43·0	0 19·0	1 16·0	55
27	−1 19·5	−31 44·0	30 24·5	30 41·5	0 17·0	1 17·5	62
Apr. 1	−1 18·0	−31 46·0	30 28·0	30 45·0	0 17·0	1 22·0	69
6	−1 11·5	−31 50·5	30 39·0	30 55·0	0 16·0	1 34·0	80
11	−1 3·0	−31 57·5	30 54·5	31 7·5	0 13·0	1 48·5	85
16	−0 55·0	−32 4·0	31 9·0	31 22·0	0 13·0	2 5·0	84
21	−0 47·0	−32 10·5	31 23·5	31 35·5	0 12·0	2 20·0	84
26	−0 38·0	−32 18·0	31 40·0	31 52·0	0 12·0	2 39·0	86
May 1	−0 29·5	−32 25·0	31 55·5	32 8·5	0 13·0	2 57·5	85
6	−0 20·5	−32 32·5	32 12·0	32 24·5	0 12·5	3 15·5	86
11	−0 12·5	−32 39·0	32 26·5	32 41·5	0 15·0	3 34·5	84
16	−0 3·0	−32 48·0	32 45·0	32 58·5	0 13·5	3 53·5	88
21	+0 8 0	−33 0·0	33 8·0	33 18·0	0 10·0	4 15·0	92
26	+0 19·0	−33 12·0	33 31·0	33 36·0	0 5·0	4 35·0	92
31	+0 28·5	−33 21·0	33 49·5	33 51·5	0 2·0	4 52·5	88

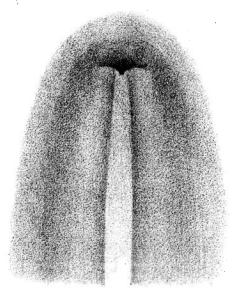
In the above pages and tables—

Sign + is used to signify that the error of chronometer is *fast* on G.M.T.

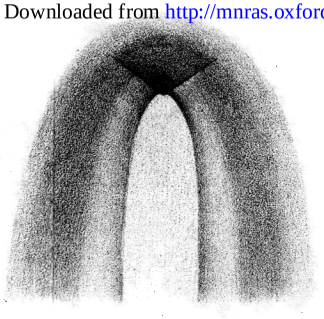
„ − „ „ „ „ *slow* „

Liverpool, 1874, *Sept.* 3.

COGGIA'S COMET



July 1. $11^h\ 0^m$



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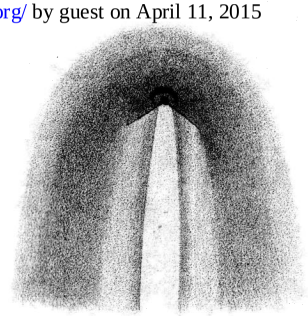

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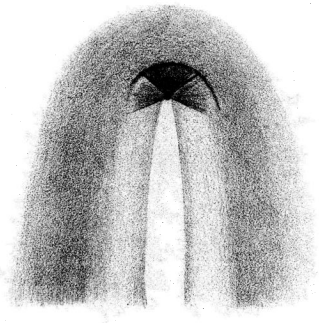
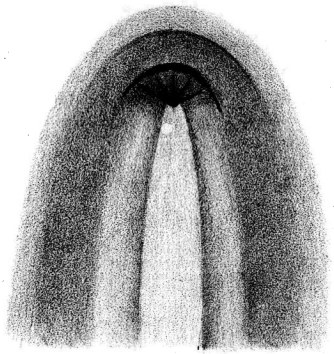
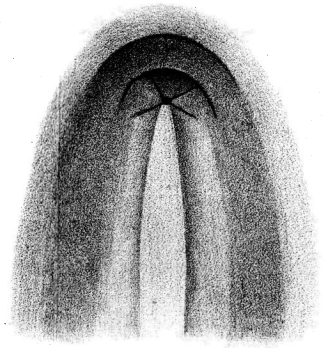


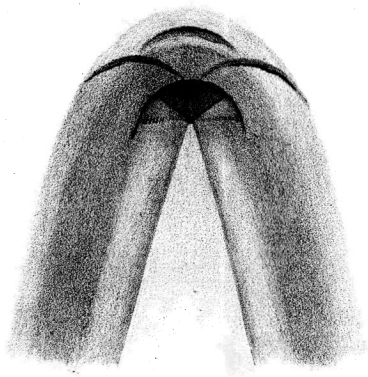
July 6. $10^h 40^m$



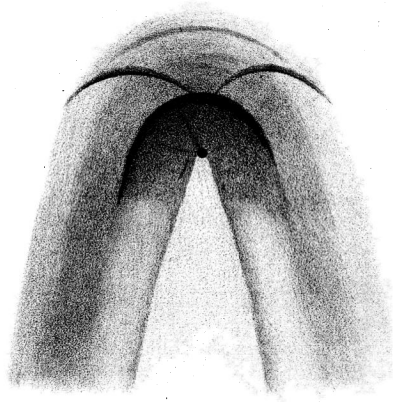
July 7. $10^h\ 30^m$



July 8. $12^h\ 30^m$



July 13. $11^h\ 0^m$



July 14. $11^h\ 0^m$

as seen in a refractor of 10 inches aperture, 12 ft. 9 in. focal length. Power 80.

Malby & Sons, lith.